【Grant-in-Aid for Scientific Research (S)】

Broad Section D

Title of Project : Biohybrid Sensor Engineering for Ultra-Sensitive Detection

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Research Project Number : 21H05013 Researcher Number : 90343110

Term of Project : FY2021-2025 Budget Allocation : 145,500 Thousand Yen

Keyword : Micro/Nano devices, Nanobio, Biosensors, Biological membranes and receptors, Hybrid/Smart/Biomaterials

【Purpose and Background of the Research】

The sense of smell and taste of living things, including humans, are utilized in various applications. For example, detector dogs and rescue dogs play an active role in detecting/searching for explosives, illegal drugs, and missing persons. This is because the molecular recognition of living things is superior to current man-made sensors in some aspects. Looking at the mechanisms of molecular recognition, proteins (receptors) in the cell membrane covering the cell surface work as sensors to recognize information from the outside world in cells. For example, ionotropic receptor, one of the sensor proteins, opens its gate when a target molecule is bound, making a nanoscale channel for ions to pass through the cell membrane. By transporting millions of ions per second into the cell through the channel, ionotropic receptor enables detection of target molecules. These sensor proteins present excellent selectivity in molecular recognition, like a key and a keyhole, and their high signal amplification function makes them superior sensor elements. On the other hand, the use of living things poses many challenges, such as reproducibility of sensitivity among different samples, the low quantitative capability, the high cost, and the limited usage environment.

Our research group has been aiming to produce "biohybrid sensor" that integrates a biological element with an engineering device to extract the functions of molecular recognition of living things. We consider that biohybrid sensor is a next-generation sensor platform that surpasses the performance of conventional man-made sensors while avoiding problems specific to living things. We succeeded in fabricating sensors using receptors or cells expressing receptors as biological elements and detected target substances such as drugs and volatile organic compounds. However, we have not yet been able to conduct deep, systematic, and fundamental research on the design theory of biohybrid sensors. In this research, we aim to establish fundamental theories that are essential for the development of biohybrid sensors.

【Research Methods】

We study the fundamental theories for the development of biohybrid sensors to utilize the molecular recognition functions of organisms directly in engineering devices. The following three research items are carried out. (1) We conduct a systematic study on the fabrication of cell arrays, which is the basis of biohybrid sensor, to understand the design theory of cell arrays in deep. From multidisciplinary aspects of cell engineering, biomaterials, and microfluidics, the methodology of cell arrangement will be examined while maintaining the molecular recognition function of the cells. (2) We conduct fundamental studies on the extraction of signals produced by biological elements as well as the conversion of the signals into quantitative data. The signals that the cells generate by recognition of target molecules show large variance in intensity. We examine the methodology that converges the conflict by theoretical and experimental approaches. (3) We validate the performance of the biohybrid sensor systems fabricated through items (1) and (2), and provide feedbacks to the design and measurement theories.

【Expected Research Achievements and Scientific Significance】

The biohybrid sensor system will be applied in a wide range of applications such as health care and safety and security, as the sensor is expected to accurately detect target molecules among mixtures with high sensitivity. Moreover, this research will contribute to understanding the theoretical backgrounds of the design and fabrication of cell arrays on an engineering device as well as extraction and quantification of cellular signals. These theories will help understand the methodology of development of various biohybrid devices using biological elements such as reactors and actuators, in addition to the sensors.

【Publications Relevant to the Project】

- Yusuke Hirata, Haruka Oda, Toshihisa Osaki, and Shoji Takeuchi: Biohybrid sensor for odor detection, Lab on a Chip, 21, 2643-2657, 2021.
- Tetsuya Yamada, Hirotaka Sugiura, Hisatoshi Mimura, Koki Kamiya, Toshihisa Osaki, and Shoji Takeuchi: Highly sensitive VOC detectors using insect olfactory receptors reconstituted into lipid bilayers, Science Advances, 7, eabd2013, 2021.
- Haruka Oda, Kazunori Kihara, Yuya Morimoto, and Shoji Takeuchi: Cell-based biohybrid sensor device for chemical source direction estimation, Cyborg and Bionic Systems, 2021, 8907148, 2021.

【Homepage Address and Other Contact Information】

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